INSTRUCTION IN SCIENCE AND ART FOR WOMEN.

NOTES

OF SIXTEEN LECTURES

(ADVANCED COURSE)

ON

"HEAT AND LIGHT,"

DELIVERED BY

PROFESSOR GUTHRIE.

IN THE

LECTURE THEATRE

OF THE

SOUTH KENSINGTON MUSEUM

DURING

NOVEMBER AND DECEMBER 1870, AND JANUARY 1871.

24. 11. 70.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

1st LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Tuesday the 15th November 1870, at 11 a.m.

1. The supposed nature of heat will be best understood after some of its effects have been examined.

2. Defining a physical force as the agent which produces an effect or change of a certain kind we may consider heat to be the force which produces change of temperature.

3. The first notions of heat are derived through the same nerves as convey the ordinary mechanical influence :—the nerves of touch : and not through the special nerves of the other senses.

4. The sensations of heat and of cold are produced when the body gains or loses heat. The terms hot, warm, cool, and cold are applied to a substance when our bodies give much or little heat to, or take little or much heat from the substance. Cold therefore is the comparative absence of heat. To get cold is to lose heat. There is no such thing as a negative quantity or a negative force.

5. With only three or four exceptions all substances get bigger as they get warmer ; they expand by heat, whatever may be their temperatures to begin with.

6. But though all substances increase in size when heated, some do to a greater amount than others. As a class, gasses expand more than liquids and liquids more than solids. All gasses expand equally for the same increase of temperature. This is neither the case with liquids nor solids.

7. The force exerted by liquids as they expand by heat is exceedingly great : and that exerted by solids is incalculable. Gases may be restrained from expanding with comparatively little effort.

24 . 11 . 70 .

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

2ND LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Friday the 18th November 1870, at 11 a.m.

1. If two bars of different metals be in contact at one end and if that end be changed in temperature, a galvanic current passes along a wire connecting the other ends of the bars. This current moves in one or the opposite direction according as the point of contact be heated or cooled. This current (and therefore the heat which causes it) may be detected by its influence on a neighbouring magnetic needle which is turned out of its position one way or the other according as the current passes one way or the other above, or one way or the other below the needle. From the degree of deflexion of the needle, the strength of the current and hence the degree of change of temperature which caused the current can be measured. The Thermopile or Thermomultiplyer is a "battery" of such couples of metallic bars of Bismuth and Antimony.

2. The expansion of solids by heat is too small and too irregular to be used for measuring temperature. Very high and very low temperatures can only be roughly determined by any means. The inequal expansion of solids (metals) is used in measuring temperature.

3. The expansion of gases through access of heat being great and uniform, the volume of a given quantity (mass or weight) of a gas is a delicate measure of temperature. But since a gas in a confined space cannot expand and in an open one it is exposed to the ever varying pressure of the atmosphere which changes its volume, gas thermometers are of comparatively limited use.

4. For most purposes the expansion and contraction of the liquids mercury and alcohol are used for shewing gain or loss of heat. The temperature of melting ice is constant: so is that of boiling water: both for reasons afterwards to be examined. The range of temperature between these two is divided into 80 equal parts or degrees in the Réaumur, 100 in the Centigrade or Celsius, and 180 in the Fahrenheit thermometer.

5. Having now a Thermometer or measure of temperature, we can examine more exactly the relation between temperature and volume in the cases of gases, liquids, and solids. A gas at any temperature heated 1° Centigrade increases $\frac{1}{273}$ of its volume. The expansion of most liquids is regular though small, that of solids is irregular.

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INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

3RD LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Tuesday the 22nd November 1870, at 11 a.m.

1. There are three ways in which heat may and does travel, namely, Conduction, Convection, and Radiation. If the point of a needle be held in the flame of a candle, the other end gradually becomes too hot to be held: this is an example of conduction. If the hot needle be moved from the flame it carries its heat with it: this is an instance of convection. If the finger be held near to the side of the candle-flame, heat is felt: this is an instance of radiation.

2. Metals are distinguished among solids for their good conducting power. Amongst metals the order of conducting power for heat is the same as that for electricity. Silver is the best conductor for both forces. Amongst non-metallic liquids, water is the best conductor for heat, and those bodies which resemble water in constitution are pre-eminent as conductors. Gases are bad conductors of heat.

3. The Gulf-stream and the artificial heating of houses exemplify the convection of heat by liquids. The winds and artificial ventilation exemplify convection of heat by gases.

4. Two wells, the water in which stands at the same level do not necessarily contain the same quantity of water even when the depths of the wells are the same. In like manner two bodies of the same temperature though they be of the same weight (or mass) do not necessarily contain the same quantity of heat. Substances have different capacities for heat, that is the same quantity of heat entering equal masses of them will heat them to different degrees.

5. In Physics, the adjective "Specific" implies the result of comparison. Specific gravity and specific heat are both ratios.

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INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

4TH LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Friday the 25th November 1870, at 11 a.m.

1. The Specific heat of a solid or liquid substance is the ratio between the capacity for heat of any mass of that substance and the capacity for heat of an equal mass of water. In the case of gases, their capacities for heat are compared with (divided by) the capacities for heat either of Hydrogen or of Air.

2. Temperature may be compared with Velocity, quantity of heat with Momentum, Capacity for heat with Density.

3. The quantity of heat in a given piece of matter depends upon the temperature of the piece, upon its quantity (mass, which may be measured by its weight) and upon the Capacity for heat of the substance of which it is made.

4. Just as mechanical work is measured by work-units so is heat-work measured by heat-units. One unit of work is spent when 1 gramme (the weight of 1 cubic centimètre of water) is raised 1 mètre. One unit of heat is spent when 1 cubic centimètre of water (1 gramme in weight) is raised 1^{0} C. in temperature. One unit of work is recovered (performed) when 1 gramme falls 1 mètre. One unit of heat is recovered (liberated) when 1 gramme of water sinks 1^{0} C. in temperature.

5. In order to heat 2 grammes of a substance 1^{0}, twice as much heat must be employed as to heat 1 gramme 1^{0}. In order to heat 1 gramme 2^{0} twice as much heat is required as to heat 1 gramme 1^{0}. *Examples*, when 7 grammes of water are heated 6 degrees, 42 units of heat are employed, when 4 grammes of water sink 12 degrees, 48 units of heat are set free.

6. If a pound of iron at 100^{0} C. is put into a pound of water at 0^{0} C. the iron will give heat to the water until the two have the same temperature. The quantity of heat lost by the iron is the quantity gained by the water. Therefore the loss of a certain quantity of heat by the iron affects the temperature of the iron more than the gain of the same quantity of heat by the water affects the temperature of the water. Accordingly the capacity for heat of iron is less than that of water or the specific heat of iron is less than 1.

7. The same quantity of heat is required to heat equally an atom of each element.

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INSTRUCTION IN SCIENCE & ART FOR WOMEN.

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SYLLABUS

OF

5TH LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Tuesday the 29th November 1870, at 11 a.m.

1. If a lump of cold ice,—say 10° below Zero Centigrade (written—10° C.) is put into a kettle over a slow fire, the heat from the fire enters the ice and warms it, until the ice reaches the temperature of 0° C. The water so formed, has and retains, this same temperature 0° C. as long as any ice remains unmelted. As soon as all the ice is melted, the water so formed begins to rise in temperature and goes on getting hotter and hotter until it reaches the temperature of 100° C. Then it begins to boil. The vapour so formed has the temperature of 100° C. as long as any water remains unvapourized. The heat which enters the ice at 0° C. and melts it without raising its temperature is called heat of liquefaction. The heat which enters the water at 100° C. and vapourizes it without raising its temperature is called heat of vapourization. The first is said to be *latent* in the water at 0° C. and constitutes the latent heat of steam. The second is said to be *latent* in the steam and constitutes the latent heat of steam.

2. If steam (at 100° C.) be passed into 100 grammes of water at 0° C. it will be condensed into water which will mix with the original 100 grammes. As it condenses it will heat the water, giving to it its own latent heat. After a time the cold water will be raised by this means to 100° C. When this temperature is reached the steam passing into it will cease to be condensed. On weighing the hot water, its weight is found to be $118\frac{1}{2}$ grammes. The increase in weight or $18\frac{1}{2}$ grammes is the weight of the steam which has passed over and whose latent heat has raised 100 grammes of water from 0° C. to 100° C., that is which has giveu up 10,000 heat units. One gramme of steam therefore at 100° C. in becoming water at 100° C. gives up $\frac{10,000}{18\frac{1}{2}}$ or about 540 heat units. So that 540 is the latent heat of steam.

3. The latent heats of vapours are found to be nearly exactly inversely proportional to their densities.

4. If 500 grammes of water at 100° C. are poured upon 100 grammes of ice at 0° C. the whole of the ice will melt and 600 grammes of water at 70° C. will result. The 500 grammes have therefore sunk 30° C. They have therefore given up 15,000 heat units. Therefore 15,000 heat units melt 100 grammes of ice and raise the ice cold water so formed to 70° C. For the latter purpose 70×100 or 7,000 heat units are necessary. Therefore $15,000-7,000$ or 8,000 heat units melt 100 grammes of ice. Therefore 80 is the latent heat of water.

5. Whenever a solid becomes liquid or a liquid becomes vapour, heat is absorbed. Whenever a liquid becomes solid or a vapour becomes liquid, heat is liberated.

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INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

6TH LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Friday the 2nd December 1870, at 11 a.m.

1. Heat is absorbed by a gas or vapour when that gas or vapour expands. Hence a body is cooled when the air around it is exhausted by the air-pump. Compressed air escaping and expanding cools bodies in contact with it. Compressed steam (above 100° C.) in escaping, requires and absorbs heat for its expansion.

2. All liquids strive to become vapours. The force of this tendency is called the tension of the vapour of the liquid. This tendency is checked by the pressure of the air. If the pressure of the air be removed evaporation takes place more quickly, heat is absorbed more rapidly by the vapour formed and cold is produced. The tension of the vapour of a liquid can be measured by measuring the depression of the mercury of a barometer when the liquid is introduced into its vacuum. The tensions of the vapours of liquids vary according to their chemical nature and according to the temperature to which they are exposed. If water in a bottle be boiled until all the air is expelled by the steam formed and the bottle be then closed and allowed to cool, no air can enter. A large proportion of the steam will condense: the elastic force or tension of the remaining steam will restrain evaporation from the water.

3. When a liquid is heated to a certain temperature, the tension of its vapour overcomes the pressure of the air and the cohesion of its own particles. If the heat be abundantly supplied so as to furnish sufficient heat of vapourization (latent heat for the vapour), the liquid boils. The temperatures at which different liquids boil depend upon the nature of the liquids and upon the pressure to which they are subjected. Thus, water *in vacuo* boils at a lower temperature than when pressed by the air (15 lbs. on the square inch).

4. Liquids may be surrounded with exceedingly hot matter without boiling. They defend themselves from the heat by throwing off vapour, which by virtue of its great thermal resistance, protects them from the surrounding heat. Liquids thus evaporating often assume a spheroidal shape because they are released from contact with and the effect of the adhesion of solid matter.

5. When radiant heat falls upon a body it may be reflected from the body's surface: or it may penetrate into the body. Heat which penetrates into the body may remain there, in which case it is said to be absorbed: or it may pass through, in which case it is said to be transmitted.

6. Radiant heat travels in straight lines. The heat which travels along one of these lines is called a ray of heat. If a ray or bundle of rays of heat be reflected, the ray or bundle makes the same angle with the reflecting surface after reflexion as it did before.

7. Smooth metallic surfaces reflect heat most perfectly.

1.12.70.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

7TH LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on
Tuesday the 6th December 1870,
at 11 a.m.

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1. A surface which readily allows heat to enter, also readily allows it to escape. Hence good absorbers are also good radiators of heat. The amount of which passes into or out of a body in a given time depends upon the extent of the body's surface. Within the same boundaries a rough surface is larger than a smooth one. Hence, within the same boundaries, a body with a rough surface absorbs and radiates more heat than when its surface is smooth. The colour has little effect upon the amount of heat radiated or absorbed.

2. Dew and Hoar frost are the result of the cooling of the earth's surface by radiation.

3. Radiant heat passes through some snbstances with little loss. Such substances are called diathermanous. Substances which refuse to let the radiant heat through and which therefore either reflect it or absorb it are called athermanous. Diathermancy may be compared with transparency.

4. Heat and Light are both given off from red hot or white hot bodies. It is possible to separate the two forces, light and heat and to get, on the one hand, dark heat (obscure heat) and on the other, cold light.,

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INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

8TH LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Friday the 9th December 1870, at 11 a.m.

1. Those substances which transmit radiant heat with little loss and are therefore highly diathermanous, resists the passage of heat by conduction and *vice versa*. Thus metals are athermanous and good conductors—so is water. Bisulphide of carbon is diathermanous and a bad conductor. Iodine is diathermanous and a bad conductor, and so on.

2. All matter is supposed to consist of particles, and all space to be filled with a medium which has mass (and therefore can have momentum and inertia) but is without weight. This medium is called Æther. Heat is supposed to be the vibration of the particles of matter. About the shape of the paths or orbits of the particles nothing is known. Some of the facts which we have examined may be explained as follows. *Temperature* is the amplitude of the particles' vibration. *Quantity of heat* in a body is the sum of the momenta of its particles. *Capacity for heat* is the inertia of its particles. *Communication of heat by contact* results from the vibration of the particles of one body setting in vibration (or increasing the vibration of) the particles of the other: as a tuning fork sets a sounding board in vibration. *Conduction of heat* is the gradually induced increased vibration of the particles of a body by the more violent motion of their neighbours. *Radiation of heat* is the communication of the vibration of the particles of the hot body to the Æther (as a vibrating tuning fork radiates waves of sound through air). Such radiant heat falling on some bodies is reflected (as sound from a smooth surface). It enters others and is absorbed (sets the particles in vibration). It passes through others (diathermanous ones) without heating them (setting their particles in vibration). *Latent heat* is possibly a change of shape of the particles' orbits without a change in amplitude.

3. The heat-vibration of a body's particles may be increased by a blow, by rubbing and by any means by which mechanical force is expended. The quantity of heat produced is directly proportional to the mechanical force expended. The unit of work is the work of raising 1 *gramme* 1 *mètre*. A *gramme* which falls has stored up in it 1 unit of work (as momentum) when it has fallen through 1 *mètre*. Four hundred and sixty *grammes* after falling 1 *mètre* (or 1 *gramme* after falling 460 *mètres*) acquire momentum equal to 460 units of work. If 460 *grammes* fall through 1 *mètre* on to an immovable solid as much heat is developed as will raise 1 *gramme* of water 1° C., that is one unit of heat is liberated. The motion of the mass of cold matter downwards is resolved by the blow into the tremulous vibration of its particles which constitutes heat. Hence 460 is called the mechanical equivalent of heat.

4. The heat produced by chemical union may be explained in a similar manner.

5. It is generally supposed that the heat of the sun is maintained by the continued hammering it receives from planets falling upon it. Their orbital momentum is converted on impact into molecular momentum. If the earth were to fall upon the sun the size of the latter would not be sensibly increased: but sufficient heat would be developed to maintain the sun's temperature for several thousands of years. Only about $\frac{1}{2300000000}$ of the sun's total heat reaches the earth.

6. The intensity of heat at different distances from a constant source of heat varies inversely as the square of the distance from that source. This law will be examined when the force Light is considered.

13.12.70.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

9TH LECTURE ON HEAT & LIGHT,

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Tuesday the 13th December 1870, at 11 a.m.

1. The hypothetical medium æther is supposed to receive and transmit light-vibrations as well as heat vibrations. The æther vibrations which constitute light are more rapid than those which constitute heat.

2. A special organ, the eye, exists for the recognition of the force light.

3. The particles of a body may either be so agitated by the action of some force in the body as to give out light or, the body may receive and reflect the ætherial agitations having their origin in another body. In the first case the body is self-luminous, in the second it reflects the light derived from the first.

4. Intense heat is accompanied by light. Different substances require different temperatures in order to become self-luminous. As a rule gases require the highest, liquids a lower, and solids the lowest temperature.

5. Light may be separated from heat and light may be produced without heat. Suchli ght is called Phosphorescent.

6. Bodies may give out light when only gently heated. Such light is called Fluorescent.

7. Bodies receiving light may retain light after the source of light is withdrawn. This reception is called Insolation. Insolation may be compared to the absorption of heat and to the sympathetic vibration of a tuning fork.

8. The velocity of light is about 190,000 miles per second. This velocity is determined (astronomically) by finding how long the appearance of a very remote celestial phenomenon requires to travel to the earth, or (terrestially) how long the appearance of a terrestial phenomenon requires to travel a known distance on the earth.

9. Light travels in straight lines.

16. 12. 70.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

10TH LECTURE ON HEAT & LIGHT

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Friday the 16th December 1870, at 11 a.m.

1. If a given quantity of a substance be spread uniformly over a surface, the thickness of the substance is inversely proportional to the extent of the surface. If a given quantity of force acts uniformly upon a surface, the intensity of the force is inversely proportional to the extent of the surface. The surface of a sphere is proportional to the square of its radius. Hence if a candle be placed in the centre of a spherical shell, the intensity of the light which falls upon the shell is inversely proportional to the square of the radius of the sphere. In general terms the intensity of light which falls on an object varies inversely as the square of the distance of the object from the source of light. This law is true of all radiant forces which are not expended in the medium through which they pass.

2. To compare the intensities of two sources of light, the distances are measured at which they effect equal illumination. The intensities of the two sources are then inversely proportional to the squares of their distances from the illuminated object. The application of this furnishes the means of Photometry.

3. Light is given out in all directions from every point of a visible object. Since light travels in straight lines, the rays of light which come from an object and pass through a hole in a screen, are in an inverted position in regard to one another compared with the rays before reaching the screen.

4. The law of reflection for light is the same as that for heat. The incident and reflected rays make the same angle with the reflecting surface or with the perpendicular thereto (normal): the incident ray, normal and reflected ray are in one plane. A ray of light reflected from a curved surface may be supposed to be reflected from the tangent to the surface at the point of impact.

5. The apparent distance of a familiar object is judged of by its apparent size. The apparent size is judged of by the sizes of the angles contained by lines drawn to the eye from the points of the object's circumference or extremities. From the above law of reflection it follows that the reflection of a body in a mirror appears to be as far behind the mirror as the object is really before it. The reflections of things in vertical mirrors are upright but laterally inverted (left handed). Objects seen in horizontal mirrors appear inverted, *etc.*

20.12.70.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

11TH LECTURE ON HEAT & LIGHT

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Tuesday the 20th December 1870, at 11 a.m.

1. One of the rays which a luminous point is giving out may enter the eye directly, another may do so after reflexion, another may enter the eye after two reflexions and so on.

2. By arranging innumerable small flat light-reflecting facettes so as to form a hollow parabolic mirror, all the rays of light which are parallel to the axis of the parabola will be reflected to the focus and, inversely, all the divergent rays which radiate from a luminous point in the focus will, after reflexion from the hollow surface of the parabolic mirror, be rendered parallel to one another.

3. A small portion of a large spherical mirror may be employed instead of a parabolic mirror without much departure from accuracy for the convergence of parallel rays to a point: and the converse.

4. The non-coincidence of all the reflected rays in one point of intersection is called the spherical aberration of the mirror.

5. In a spherical mirror the centre of curvature is the centre of the sphere of which the mirror is a part. The centre of the mirror is that point on the mirror which is at equal distances from all points of the mirror's circumference. The aperture is the angle at the centre of curvature made by opposite lines drawn to the circumference. The principal focus is the focus for parallel rays.

6. The principal focus of a spherical mirror is approximately half-way between the centre and centre of curvature.

7. The focus of a luminous point on the mirror's axis is also on the axis: its distance from the centre of the mirror varies with the distance of the luminous point.

8. An image is a collection of foci.

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INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

12TH LECTURE ON HEAT & LIGHT

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Friday 20th January 1871, at 11 a.m.

1. Light generally only travels in straight lines as long as it travels through matter of one uniform kind (homogenous). When it passes from one (transparent) medium to another, its path is almost invariably broken at the boundary surface. Such alteration in the light's direction is called its refraction. The angles of incidence and refraction are the angles between the perpendicular to the boundary surface at the point of incidence and the incident and refracted rays respectively. The actual amount of refraction which a ray of light undergoes in passing from empty space into a given medium depends upon the angle of incidence: being greater as the angle of incidence is greater. The ratio between the "sine"* of the angle of incidence: and the sine of the angle of refraction is constant for the same medium, whatever be the angle of incidence. This constant ratio is called the index of refraction of the medium.

2. When a ray of light passes from vacuum into any substance, it is invariably bent towards the perpendicular to the refracting surface: that is, the angle of incidence is greater than the angle of refraction and accordingly the sine of the first is greater than the sine of the second or the indices of refraction of all substances are greater than unity. If a ray of light passes out of any medium into vacuum, it is bent away from the perpendicular to the surface, to the same amount as it would be bent towards the perpendicular on entering the medium along the same path along which it actually leaves the medium.

3. Gases refract light so much less than solids and liquids that the refraction of a ray passing out of air into a solid or liquid is nearly the same as if it passed out of vacuum into the same.

4. If a ray of light fall obliquely on a transparent solid having parallel faces, it will, on emerging from the second face, have a direction parallel to but not continuous with its original direction. If the ray strike the side of a wedge or prism parallel to the base of the prism, it will be refracted both on entering and emerging from the prism: both of these refractions will incline the ray towards the prism's base.

5. From the fact that the refractive index is constant, it follows that when a ray of light travelling in a substance strikes the surface at a certain angle it is refracted along the substance's surface. If it strike the surface yet more obliquely it is reflected from that surface. Hence the surface of a transparent substance may be employed as a metallic mirror. This is called total reflexion: and the angle at which refraction ceases and reflexion begins is called the critical angle.

6. The refractive index depends partly upon the density but chiefly upon the chemical nature of the substance.

*The steepness of a hill may be measured by comparing the height of any point of it above the plain with the length of the straight road from that point to the foot of the hill. The result of this comparison (ratio) is the sine of the hill's steepness. Every angle may be regarded as the steepness of a hill.

26.1.71.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

13TH LECTURE ON HEAT & LIGHT

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Tuesday 24th January 1871, at 11 a.m.

1. An ordinary lens may be regarded as consisting of a great number of pieces of prisms of various refracting angles so arranged that they refract the incident rays all to one point called the focus. The principal focus is the focus for parallel rays. Either face of a lens may be plane, convex, or concave, and the path of the light after passing through the lens depends upon the shape of both surfaces.

2. As in the case of reflecting mirrors, so the luminious rays from a point may be collected after passing through the lens into another point which is the focus of the first. A collection of such foci forms an image. If a body in a place A gives an image in a place B, then if the body be placed at B the image will be at A.

3. Spherical convex lenses like spherical mirrors do not concentrate all the parallel rays to one point: this imperfection is called the spherical aberration of the lens.

4. The eye is a dark spherical chamber filled with transparent liquids and semi-solids, the boundary surfaces and refractive powers of which are such that the images of external objects are thrown upon the back of the inside of the eye-ball. A ray of light entering the eye encounters first the *cornea*, a hard transparent colourless surface more convex than the remainder of the eye-ball. It then passes through the transparent liquid (*vitreous humour*) immediately behind the cornea. Most of such light is intercepted by the opaque membranous curtain the iris, which is differently coloured in different individuals. In the centre of the iris is a hole, the *pupil*, which can be enlarged or diminished. The light which passes through the pupil immediately encounters a double convex lens, the crystalline lens which is semi-solid and contains *aqueous humour*. On emerging from this the ray enters the chief cavity of the eye which is filled with vitreous humour. It finally strikes upon a network of nerves, the *retina* which is a cup-like ramification of the optic nerve which enters the back of the eye-ball at the *punctum cæcum*.

5. An impression produced on the eye endures for a time after the light which produces it is extinguished: this is called the duration of images. Not only the parts of the retina which receive the light but the neighbouring parts also are affected: this is called irradiation.

27.1.71.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

14TH LECTURE ON HEAT & LIGHT

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Friday 27th January 1871, at 11 a.m.

1. If a beam of white light fall upon a prism of any refracting substance the whole of the light is bent towards the prism's base. Some of the beam is more strongly refracted, some less; so that on emerging the beam is found to consist of divergent rays. These divergent rays are found to have different colours. The rays most refracted are coloured violet, those next are indigo, then the blue, green, yellow, orange, and red, in succession. These variously coloured rays are supposed to exist in the original beam of white light: and the white light is said to be analysed by the prism.

2. If the variously coloured rays thus separated from one another by one prism be received upon a second prism exactly similar to the first but placed in an inverted position, the rays separated by the first will be recombined by the second prism and white light reproduced.

3. The colours so produced by analysis are called the prismatic colours, and the various coloured rays constitute the *spectrum*. If these colours are presented singly to the eye in rapid succession, the effects are blended together in consequence of the retention of images by the eye and the sensation of white light is produced.

4. In measuring the refractive index of a substance the refraction which the purest yellow ray undergoes is measured.

5. Two substances may differ from one another not only in their refractive indices, but also in their power of separating the variously coloured rays. The power of separating the rays is called the chromatic dispersive power and is measured by the length of the spectrum. An ordinary simple lens gives images fringed with colour, each ray of white light being decomposed into coloured rays that is giving rise to a spectrum, these spectra overlap one another except at their extremities. By combining lenses of substances of different refractive angles and different dispersive powers, the spectra may be made to coincide so that white light is produced. Such are achromatic lenses.

6. A blue opaque body is one which reflects blue rays only, absorbing those of all other colours, and so for other colours. A blue transparent body is one which transmits only the blue rays, absorbing all other colours; and so for other colours. Hence, no red light can pass through a deep blue glass, and no yellow light can be reflected from a red opaque body.

7. The eye appears to endeavour after white light.

31.1.71.

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

15TH LECTURE ON HEAT & LIGHT

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on Tuesday 31st January 1871, at 11 a.m.

1. The heat which accompanies the light of the sun, of the electric lamp, and all light produced by chemical change, is refracted with the light and is found throughout the luminous spectrum. On using prisms made of different substances, the maximum intensity of the heat is not found invariably associated with any particular colour, but always inclines towards the red end of the spectrum: that is, heat is, on the whole, refracted less than light.

2. Besides the rays of heat and light, the emanation from the sun, the electric lamp, and fields of intense chemical activity, contain rays which promote chemical change These are called the *actinic* rays. By their aid the colouring matter of leaves is developed, and the green leaves decompose the carbonic acid of the air in the presence of water, liberating oxygen from it and forming wood, starch, gum, sugar, etc., which are all carbonic acid deprived of some oxygen and united with water. The same actinic rays decompose salts of silver, etc., reducing the silver ultimately to the metallic state. Such decomposition forms the basis of photography. These actinic rays also undergo refraction and indeed are more strongly refracted than the heat and most of the light rays, so that in the spectrum they are found at and beyond the violet end.

3. If an image of the solar spectrum be magnified, it is found to be crossed by black lines which are innumerable: this shows that the solar light is destitute of rays of the degree of refrangibility corresponding with these lines. It is supposed that the incandescent body of the sun gives out light of all degrees of refrangibility, and that if no solar atmosphere existed a spectrum uninterrupted by black lines would be produced: further it is supposed that the various vapours in the solar atmosphere absorb and arrest light of various degrees of refrangibility thereby withdrawing such from the solar light which reaches the earth and so giving rise to the black lines. The argument in support of this is the fact founded on experiment that the generally transparent vapour of any substance is opaque to the rays which that substance in an incandescent state emits.

31 . 1 . 71 .

INSTRUCTION IN SCIENCE & ART FOR WOMEN.

ADVANCED COURSE.

SYLLABUS

OF

16TH LECTURE ON HEAT & LIGHT

TO BE DELIVERED BY

PROFESSOR GUTHRIE,

In the Lecture Theatre, South Kensington Museum, on
Friday 3rd February 1871,
at 11 a.m.

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1. Light like heat is supposed to be caused by the undulations produced in the universal medium æther. When a wave of sound passes through air or any ponderable medium, the particles of the medium move to and fro in the direction of the sound's transmission. The parts of the æther are supposed to move perpendicularly to the path of light : and thus to resemble in their motion the parts of a liquid's surface along which a wave passes.

2. Rest is maintained when two equal and opposite impulses are given simultaneously to a body. Silence is maintained when two equal and opposite efforts act upon a mass of air, one to expand and the other to compress it. Darkness is maintained when two simultaneous equal efforts are made to move the æther in opposite directions.

3. Colour is the pitch of light.

4. A bright metallic surface reflects all the ætherial undulations. Every transparent substance on receiving a ray consisting of variously vibrating ætherial waves analyses those waves partly into two systems whose planes of vibration are at right angles to one another. Each system is polarized that it has a definite plan of vibration. The angle at which incident light has to fall in order to be most perfectly polarized depends upon the nature of the substance which receives the light.

5. Certain crystals only allow those waves of light to pass through whose planes of vibration are parallel to one axis of the crystal. Light thus sifted by one crystal will pass freely through a second crystal of the same substance placed parallel to the first, but will be arrested if the second crystal is perpendicular to the first. If the plane in which the æther particles are moving after the light has passed through the first crystal be turned through a right angle before falling upon the second, then the light polarized by the first will pass freely through the second.

6. A ray of light which enters a mass of Iceland spar is divided into two rays both of which are polarized and in planes at right angles to one another.

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QUESTIONS
ON
LIGHT AND HEAT.
Advanced Course, 1870—71.

Paper I.

1. Explain why the sensation of heat or cold cannot be used as a guide to the temperature of a body.

2. A gas expands $\frac{1}{273}$ of its volume for every 1° C. increase of temperature. Its volume also varies inversely with the pressure applied to it. Yesterday the temperature was 10° C. and the barometer stood at 750 *millimètres*. To day the temperature is 0° C. and the barometer stands at 760 *millimètres*. If you had taken 100 cubic centimètres of air yesterday, what would you find the volume to be to day?

3. A thousand cubic centimètres of air at 0° C. weigh $1\frac{1}{3}$ grammes. A balloon weighs $\frac{1}{10}$ of a gramme and holds 1000 cubic centimètres. It is filled with air at 100° C.: will it rise or sink? (With what force in either case?)

4. Describe experiments to show that water expands on freezing. How does an iceberg prove the same fact?

5. A cup of water has the temperature of 50° F., what is its temperature R. and what C.? Mercury boils at 360° C., at what temperature F. and R. does it boil?

6. How is it that ice is wrapped in flannel to keep it cool, and a foot warmer in flannel to keep it warm? Cotton wool and calico are chemically the same: how is it that, taking equal weights, the calico is a worse protector against cold than the wool?

7. Explain fully the construction and action of Davy's lamp.

8. Bread may be toasted nearly as quickly below a clear fire as above it. But the water in a pot will boil far sooner when placed above than when placed below. Why this difference between the bread and the water?

9. If you put two kettles, one filled with a pound of oil and the other with a pound of water, on the same fire, the oil will be heated the soonest. Why?

10. Describe clearly what is meant by a unit of heat. 100 grammes of water at 70° C. sink to 10° C., how many units of heat are lost?

11. Two pounds of boiling water are mixed with 1 pound of water at 0° C., what will be the temperature of the mixture?

N.B.—The answers to these questions may be given in on Friday the 9th December.

27 . 1 . 71

QUESTIONS

ON

HEAT AND LIGHT.

Advanced Course, 1870—71.

PAPER II.

1. What is meant by the mechanical equivalent of heat, and how can it be measured? What is supposed to be the difference in the conditions of the particles of a hot and a cold body, and how is this connected with the expansion of bodies by heat?

2. What is meant by Diathermancy? What relation exists between the diathermancy of liquids and their thermal resistance?

3. Describe an experiment by which the velocity of light has been determined.

4. If you can just see to read by moonlight and also by a candle four yards off, how much brighter is the moon than the candle? (1760 yards in a mile. Distance of moon 239,000 miles).

5. Draw a full length sketch of a person seeing the reflection of himself in a vertical mirror.

6. How is it that objects seen in a convex spherical mirror appear small, upright, and behind the mirror.

7. Trace (giving figure) the course of a ray of light (1) falling obliquely on a slab of glass, (2) falling on one face of a prism, parallel to the base of the prism, (3) falling on a double concave lens parallel to the axis of the lens.

8. Give a drawing showing the decomposition of white light by a prism, and show where in the luminous solar spectrum the heat rays most abound.

9. What is colour?

N.B.—The answers to the above questions may be given in on Tuesday the 31st January.